§7. Density Profile and Microturbulence in LHD

Tanaka, K., Mikkelsen, D.R. (Princeton Plasma Physics Laboratory), Michael, C.A. (Australian National Univ.), Vyacheslavov, L.N. (Budker Institute of Nuclear Physics SB RAS)

Understanding physical mechanisms for the determination of electron density profiles is one of the essential issues for the control of a future fusion reactor. The neoclassical mechanism, driven by collisions of confined particles, is too weak to be responsible for observed density profiles in tokmaks and helical devices in many experimental observations. In LHD, neoclassical transport was found to play a role for core particle convection at R_{ax}>=3.6m, where R_{ax} is the magnetic axis position, while anomalous effects seem to play a significant role for core diffusion at R_{ax}<=3.6m [1]. Thus, turbulence effects for particle transport are important in LHD. However, the role of turbulence in formation of the density profiles is not clear experimentally because turbulence measurements in the plasma core have been very limited. In order to investigate the effects of turbulence driven particle transport, plasma density fluctuations in spectral range f=20-500kHz, k=0.1-1mm^{-1} (poloidally dominated) were measured by 2D-Phase Contrast Imaging[2]. Linear and quasi-linear characteristics of turbulence and turbulence driven particle transport were studied by using gyrokinetic code GS2 [3].

Figure 1 shows T_e, T_i, N_e, fluctuation phase velocity and fluctuation amplitude profiles of R_{ax}=3.5m and R_{ax}=3.6m. Heating is 10MW NBI for both cases. Figures b-1 and b-2 show [1] peaked and hollowed density profiles at R_{ax}=3.5m and R_{ax}=3.6m respectively. Neoclassical transport is similar at ρ=0.4-0.7 because of almost identical effective helical ripples, thus, the n_e profile difference is due to the effect of anomalous transport [1]. As shown in Fig.1 (d-1) and (d-2), peaks of fluctuation amplitude are visible at ρ~0.7 and ρ~1.0 at both configurations. The clear difference between turbulence characteristics for these configurations is propagation direction of the component having peaks around ρ~0.7 as shown in Fig.1 (c-1),(c-2). It propagates to the electron and ion diamagnetic directions in the laboratory frame at R_{ax}=3.5m and R_{ax}=3.6m respectively. The measured poloidal E_rxB_t velocityby CXS at closest to ρ=0.7 location is near to zero, thus, the measured propagation direction can be related to the plasma frame as well. This suggests that turbulence at R_{ax}=3.5m and 3.6m are Trapped Electron Mode (TEM) and Ion Temperature gradient mode (ITG) respectively. Figure 2 (a) shows growth rate (γ) and real frequency ω_r) calculated by GS2. As shown in Fig.2 (a), the growth rate is clearly higher at R_{ax}=3.5m. This may correspond to higher contribution of anomalous particle transport at R_{ax}=3.5m [1]. The real frequency is the ion diamagnetic one in both cases. However, ω_r at R_{ax}=3.5m is closer to zero indicating the increase of TEM contribution. This qualitatively agrees with measurements, which suggests that turbulence is dominated by TEM at R_{ax}=3.5m.

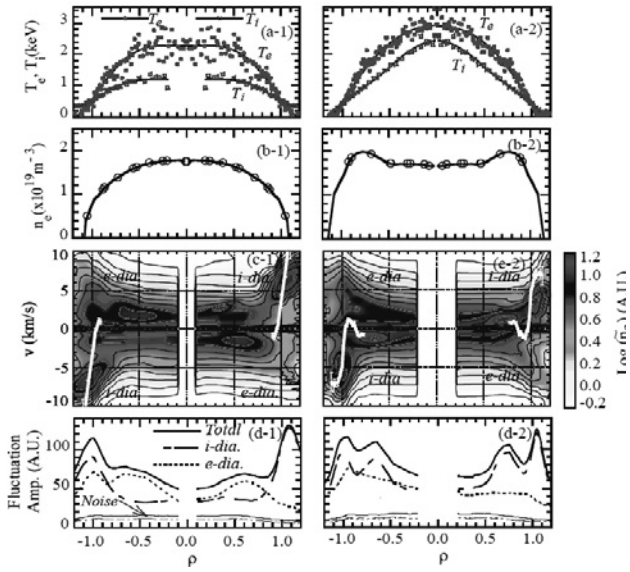

Fig.1 Profiles of (1) T_e, T_i, (2) n_e ,(3) phase velocity, and (4) fluctuation amplitude. Contours of (4) are Log(amplitude). E_rxB_t rotation velocities are plotted by the white line in (4) (a-1,b-1,c-1) $R_{ax=}$3.5m, Bt=2.8T, (a-2,b-2,c-2) R_{ax}=3.6m,Bt=2.75T

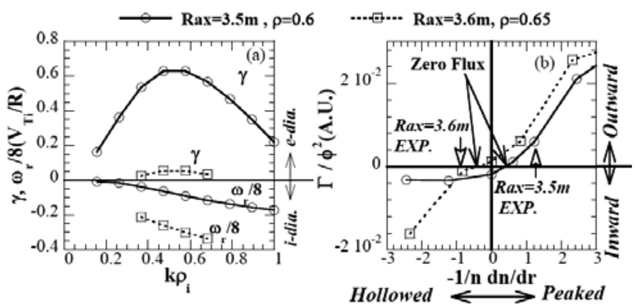

Fig.2 (a) Growth rate and real frequency, (b) Density gradient dependence of quasi linear particle flux.

Figure 2 (b) shows density gradient dependence of quasi-linear particle flux. Calculations were done at ρ=0.6 and ρ=0.65 for R_{ax}=3.5 and R_{ax}=3.6m respectively, where particle source is negligible and density gradient is opposite at both configuration. In the steady state of core region, where particle source is close to zero (ρ<~0.9), particle flux should be zero. Plasma parameters such as T_e T_i gradients, T_e/T_i, and collisionality were kept constant in calculations while experimental values and normalized density gradients were scanned to search zero flux condition. As shown in Fig.2(b), the normalized density gradient, which determines zero flux condition of both experiment and gyrokinetic predictions, is positive at R_{ax}=3.5m and negative at R_{ax}=3.6m. This shows that gyrokinetic prediction qualitatively agrees with the experimental observation. The remaining discrepancy may be due to contribution of the neoclassical particle flux and NBI particle deposition.

1) Tanaka, K., et al.,Fusion Sci., Tech, 70 (2010)
2) Tanaka, K., et al., Rev. Sci. Instrum. 79, 10E702 (2008)
3) Dorland ,W., et al., Phys. Rev. Lett. 85, 5579 (2000)